1994 Annual Progress Report
Executive Summary

Turfgrass Irrigation With Municipal Effluent: Nitrogen Fate, Turf Kc Values and Water Requirements

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This project is being conducted to 1) determine the potential movement of nitrogen contained in municipal secondarily treated wastewater used to irrigate turf; 2) determine how effluent irrigation influences the water and nitrogen requirements of turf; 3) compare how accurately five Penman equations used in the western United States predict actual turfgrass water use; and 4) accumulate an atmospheric database and turfgrass water use database which can be used by the public and private sector to develop and test the accuracy of evapotranspiration equations.

Atmospheric and turfgrass water use data collection began in 1995 following about eight months of data collection with bare soil. The data continues to show that the two giant weighing lysimeters are behaving similarly and accurately. The various Penman equations being tested in this project indicate that all equations respond similarly to changes in atmospheric conditions. Some variation does exist in how well these equations predict actual turf water use as measured by the lysimeters. All of the equations overestimate turf water use. The Kc values (ratio of actual turf water use to predicted water use) of this bermudagrass turf appear to be 86% to >100%, depending on the particular equation. This is higher than currently reported in the literature but may be due to the immaturity of the bermudagrass turf stand in 1994. Next years data should clarify this issue. An atmospheric and turfgrass water use database is being collected and will become available to the private and public sector for ET equation development and testing after completion of this project. It will provide more atmospheric data than is usually needed for calculating ETo. This additional information may be useful in determining why predicted water use values differ from actual water use. Data collection is completed for the 1994 bermudagrass growing season and has begun on winter overseeded ryegrass. This data will shed light on the water requirements of winter turf, particularly in the spring when air and soil temperatures increase. The fate of N applied to turf in the lysimeters shall be conducted in Summer 1995 after the bermudagrass is fully mature.

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Project Description: This project is designed to 1) determine the potential movement of nitrogen contained in municipal secondarily treated wastewater used to irrigate turf; 2) determine how effluent irrigation influences the water and nitrogen requirements of turf; 3) compare how accurately five Penman equations used in the western United States predict actual turfgrass water use; and 4) accumulate an atmospheric database and turfgrass water use database which can be used by the public and private sector to develop and test the accuracy of evapotranspiration equations.

BRIEF OVERVIEW OF KARSTEN LYSIMETER OPERATION

This project is being conducted with the two giant weighing lysimeters at the Karsten Laboratory and Desert Turfgrass Research Facility. Each lysimeter is 2.5 m wide x 4 m deep allowing for soil and soil water sampling well below the turfgrass rootzone. Samplers are located throughout the lysimeter for a total of 90 ports/lysimeter. Each lysimeter sits on a modified Cardinal truck scale having an accuracy of ± 200 g. This is equivalent to the gain or loss of 0.04 mm water at the lysimeter surface. The lysimeters became operational during Fall 1993 and were calibrated using bare soil evaporation and drainage. Since the inception of turfgrass irrigation on 3 June 1994, we have completed installing the remainder of the monitoring devices for measuring soil water tension, and temperature. The wetting front migration through the deep soil profile was successfully measured using the tensiometers and Time Domain Reflectometry probes. Comparison of the data should provide excellent correlation to the water retention curves that we have from our laboratory experiments on campus, and, possibly, from the values obtained from Turf Diagnostics (Olathe, KS) using their sample methods with the same soil. The soil water wetting front has reached the bottom of both tanks, so monitoring frequencies with tensiometers and TDR probes likely will be reduced. Both the stainless steel and ceramic solution samplers were activated daily for soil water collection at successive depths until tracer bromide levels were no longer detectable above background. The method of solution collection was successful, and no samplers failed during the past several months. Over 1200 soil water samples have been collected to date. Data showing simultaneous migration of water and bromide is currently being analyzed by Michael Young and Peter Wierenga. Computer modeling of the data should be interesting from a soil physics standpoint, and hopefully will lead to refereed publications. Anion migration through the soil will be useful when labelled nitrate-N is applied to the tanks in 1995.

The data management system for reducing and storing data and information from the lysimeters appears to be operating successfully. A mainframe computer account was created for storing and transferring weekly ET data from Michael Young, who is managing the data reduction, to Duane Otto, who is analyzing the data using different ET equations. The use of the mainframe account is efficient, as data can be easily moved from one computer to another at any time of the day or night, without the use of hard copies.

IRRIGATION SYSTEM AND TURF ESTABLISHMENT

Plantbed preparation was completed for installation of the irrigation system in January. The irrigation was then installed over the course of several months. As described in the previous report the land needed deep ripping to alleviate compaction due to construction. Rocks and stones were removed. Composted mulch was incorporated to a depth of 60 cm to enhance turf performance. Surface grading was done to ensure that surface water does not accumulate around the lysimeters stairwell, evaporative cooler, and utility boxes.

A dual irrigation system was installed for each lysimeter following land preparation. One system can deliver wastewater while the other delivers potable water. Zero trajectory heads were installed to prevent drift from one tank to the other. A wind speed shut-off switch has been installed as part of the Rainbird Maxi-5 weather station to prevent the irrigation system from running should wind speed exceed 4.8 km/h. Multiple irrigation valves were also installed to prevent over-irrigation due to a failed valve. The remainder of the irrigation system, i.e. that irrigating the surrounding turf was installed and is controlled by the wind speed shut-off switch. The irrigation system was completed in April.

As a result of the extensive trenching involved in installing the irrigation system the lysimeter area had to be regraded. This has been accomplished, the heads and valve boxes set, and the area prepped for hydrosprigging. A-G Turf Farms donated the 'Tifway' bermudagrass sprigs and performed the hydrosprigging. Hydrosprigging occurred on 2 June 1994 at a rate of 1.0 m^3 $100m^2$(25 bu/1000 ft^2). Irrigation was applied as necessary to prevent desiccation. Fertilizer was applied to promote rapid establishment. Full groundcover was achieved on the lysimeters by 22 August. Irrigation water applied and turf water use were monitored during establishment and throughout the remainder of the bermudagrass season.

As you are aware, an irrigation malfunction occurred shortly after hydrosprigging and led to a severe flooding of the East Lysimeter. Soil flowed out of the bottom ports, leading us to strongly question the future use of the 3.5 m and 4 m deep monitoring devices. However, this incident in no way affects the use of that lysimeter for the USGA project. This conclusion stems from several observations: 1) both the East and West Lysimeters were recalibrated during July, 1994, a month after the flooding event. The East Lysimeter scale mechanism and loadcell calibrated to an r^2 = 1.0000, with no significant drift in slope, indicating that the weighing system is functioning properly; 2) The surface soil is intact on the East Tank. Any caving that may have occurred does not seem to be affecting the growth of the turf. We don't know whether cavitation will lead to surface caving, but for the time being, we have excellent turf cover with no visible adverse affects; and 3) Measurements of actual evapotranspiration from both lysimeters are within 0.5% of each other. Table 1 compares the total weekly turf evapotranspirational losses from the two lysimeters over our study period.

Overseeding of the lysimeters and the surrounding bermudagrass occurred on 1 October. The bermudagrass was scalped to a mowing height of 1.25 cm. The area was then overseeded with 'Froghair' intermediate ryegrass (*Lolium multiflorum x perenne*) at a seeding rate of 488 kg ha^{-1}. The rye is being fertilized and irrigated as needed for establishment.

On 1 November we will switch the irrigation water source for the West Lysimeter from potable to reclaimed water. We will then monitor for any differences in turf water use as a result of irrigation water source.

TURF ET AND METEOROLOGICAL DATABASE

A key component of this project is the development of a database containing 1) turf water use as measured by the lysimeters and 2) meteorological data necessary to compute reference or potential evapotranspiration using various forms of the Penman Equation. This database will be made available to the turf industry at the completion of this project and should serve as a calibration database for private and public entities engaged in the business of providing weather-base estimates of turf water use.

The meteorological equipment was installed in July over a well-maintained grass surface located approximately 10 m to the south of the lysimeter site. The project's primary instrument package monitors air temperature (Ta), humidity (h), wind speed (U), incoming and reflected solar radiation (SRi and SRr), net radiation (Rn) and soil heat flux (G) as detailed below. Two additional general purpose weather stations are located adjacent to the primary instrument package and serve as backup sources of meteorological data when service and/or calibration must be performed on the primary instrument package. The entire instrument package became fully operational on 1 August.

Ta and U are being measured at 1.0, 2.0, and 3.0 m above ground level (agl) to provide data for the necessary Penman Equation computations (data from 2.0 m agl)

and for the purposes of assessing atmospheric stability. An additional Ta sensor is located with a relative humidity (RH) sensor at 2.0 m agl to provide the necessary h parameters including RH, actual and saturation vapor pressure, and vapor pressure deficit. SRi and SRr are measured at 1.0 m agl using pyranometers. The pyranometer measuring SRr is inverted and mounted just underneath the pyranometer measuring SRi. A net radiometer located at 1.0 m agl measures Rn while G is measured using a combination approach which combines G data obtained from flux plates located 10 cm below the surface with calorimetric estimates of surface G obtained from measurements of soil temperature and soil physical properties.

All meteorological data are collected using Campbell Scientific 21X Microloggers. The microloggers monitor sensor outputs every 10 seconds and summarize the data into relevant totals and/or means every 10 minutes. Data stored in the microloggers are transferred to a personal computer at regular intervals, then entered into a database developed using Quattro Pro, a commercial spreadsheet software.

EVALUATION OF REFERENCE ET EQUATIONS

A second component of this project is to compare turf water use obtained from the lysimeters with estimates of reference ET (ETo) computed using the ETo equations presently used by the public weather networks in the desert southwest. Arizona, New Mexico, California and Southern Nevada presently provide ETo information to the public. The ETo equations used by the four states are derived from just two general forms of the modified Penman Equation. Arizona and California use the Penman equation recommended by Snyder et al. (1985) which computes ETo using hourly time steps (requires hourly weather data). The Arizona and California computations differ only in the handling of the Rn. Arizona estimates net radiation and California uses measured net radiation.

New Mexico and Southern Nevada use the form of the Penman Equation described by Jensen (1974) which computes ETo using daily time steps (daily weather data). Both New Mexico and Nevada deviate from the exact Jensen approach by modifying the procedure for estimating Rn.

We have also added a Penman-Montieth equation described by Allen (1986) and Allen et al. (1989) as a superior ETo estimation method. This Penman-Montieth Equation also computes ETo using daily time steps and differs from the four state-based Penman Equations by using a more realistic approach to modeling aerodynamic resistance and by incorporating canopy resistance into the equation.

N FERTILIZER FATE

This portion of the project is to monitor the fate of N applied to the turfgrass from fertilizer and reclaimed water. This objective will be fulfilled in the summer of 1995 when the turf is fully mature.

RESULTS AND DISCUSSION

Figure 1 shows that the two lysimeters are yielding similar values for turf ET. For the entire period depicted in Figure 1, the East Lysimeter used 3.5% more water than the West Lysimeter. As turf canopy cover was less than 100% prior to 22 August one should expect some differences in ET during this period. Following canopy closure, the two lysimeters agreed more closely with total turf water uses differing by only 0.5%. Table 1 shows the weekly cumulative ETa for both lysimeters. Weekly differences for ETa varied from 1.2 to 3.5 mm.

While the two lysimeters do seem to be working quite well, we have chosen for this time period to compare ETo estimates with ETa obtained only from the West Lysimeter (Figures 2 and 3; Table 2). The aforementioned problem with flooding and excess drainage is the reason for not using the East Lysimeter at this time. As of late September, drainage in the East Lysimeter had slowed considerably and our future results will utilize both lysimeters.

Figures 2 and 3 show the computed daily ETo values using the various Penman equations and the ETa from the West Lysimeter. ETo, as computed by the four state methods always exceeds actual turf ET. This is an expected result since ETo is supposed to estimate ET from a tall (8-15 cm), well-watered, cool season grass surface. Previous work in these states suggests that an appropriate crop coefficient (Kc; ratio of actual ET to ETo) for bermudagrass turf should range from 0.5 to 0.8. Kc values for our turf trend upward during much of August and September (Table 2). This increase probably resulted from increased turf water use as the turf canopy increased to 100% groundcover. During the final two weeks of complete groundcover included in this report (weeks ending 1 and 8 September), the Kc values for Arizona, California, southern Nevada and New Mexico were 0.92, 0.89, 0.88 and 0.86, respectively.

Estimates of ETo computed from the Allen et al. (1989) modification of the Penman-Montieth Equation were slightly greater than actual turf ET prior to complete canopy cover, but then declined below actual turf ET when canopy cover was complete. Crop coefficients computed during September using this equation averaged about 1.08. Our assessment as to why this equation is seemingly underestimating ETo indicates the problem rests mainly in the procedure used to estimate Rn. The Allen et al. (1989) procedure does not actually measure Rn, but estimates it instead. It appears to underestimate Rn by nearly 12%. This 12% underestimation translates into an 8% to 10% reduction in computed ETo. A 10% increase in the Penman-Monteith values of ETo would lower the Kc values obtained during the period of complete canopy cover to 0.99, about 10% greater than the average Kc value obtained by the four state methods.

The Kc values in Table 2 seem somewhat high when compared with Kc values previously reported in the literature for bermudagrass turf. However, it is possible that high first-year Kc values are linked to the relative 'newness' of the grass and the cultural practices employed to ensure optimal development of the turf (e.g. multiple, light irrigations during many days). Kneebone and Pepper (1985) suggested this to be a

consumptive water use. The 1995 bermudagrass season should help clarify this issue.

CONCLUSION

Atmospheric and turf water use data collection began in 1995 following about eight months of data collection with bare soil. The data continues to show that the two giant lysimeters are behaving similarly and accurately. The various Penman equations being tested in this project indicate that all equations respond similarly to changes in atmospheric conditions. Some variation does exist in how well these equations predict actual turf water use as measured by the lysimeters. All of the equations overestimate turf water use. The Kc values of this bermudagrass turf appear to be 86% to >100%, depending on the particular equation. This is higher than currently reported in the literature but may be due to the immaturity of the turf stand. Next years data should clarify this issue. The atmospheric and turfgrass water use database is being collected. This database will become available to the private and public sector for ET equation testing after completion of this project. It will provide more atmospheric data than is usually needed for calculating ETo. Data collection has now begun on the bermudagrass overseeded with intermediate ryegrass. The fate of N applied to turf in the lysimeters shall be conducted in Summer 1995 after the bermudagrass is fully mature.

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Table 1. Reference ET (ETo), as calculated by five different methods, in comparison to actual turfgrass ET (ETa) measured by the Karsten Giant Weighing Lysimeters.

Week Ending	ETo					ETa	
	P-M†	AZ	CA	NV	NM	W	E
	(mm/wk)						
04-Aug-94	38.8	47.8	48.3	49.7	52.6	36.4	38.9
11-Aug-94	49.4	58.2	60.4	62.2	64.2	45.0	46.4
18-Aug-94	41.3	50.1	52.0	53.0	54.1	40.7	44.2
25-Aug-94‡	22.4	25.8	27.3	27.9	28.2	22.9	24.1
01-Sep-94	40.6	47.6	49.7	50.3	51.5	43.5	44.8
08-Sep-94	34.4	41.0	41.9	42.9	43.9	38.1	36.2

†Penman-Montieth as modified by Allen et al. (1989).
‡Only four days of data.

Table 2. Weekly Kc values determined by ETo/ETa.

Week Ending	Kc				
	P-M†	AZ	CA	NV	NM
04-Aug-94	0.940	0.762	0.755	0.733	0.692
11-Aug-94	0.912	0.774	0.746	0.724	0.702
18-Aug-94	0.985	0.813	0.783	0.768	0.752
25-Aug-94‡	1.023	0.887	0.836	0.820	0.811
01-Sep-94	1.072	0.915	0.876	0.866	0.845
08-Sep-94	1.107	0.930	0.910	0.890	0.869

†Penman-Montieth as modified by Allen et al. (1989).
‡Only four days of data.

Figure 1. Comparison of bermudagrass turf water use in the East and West Lysimeters.

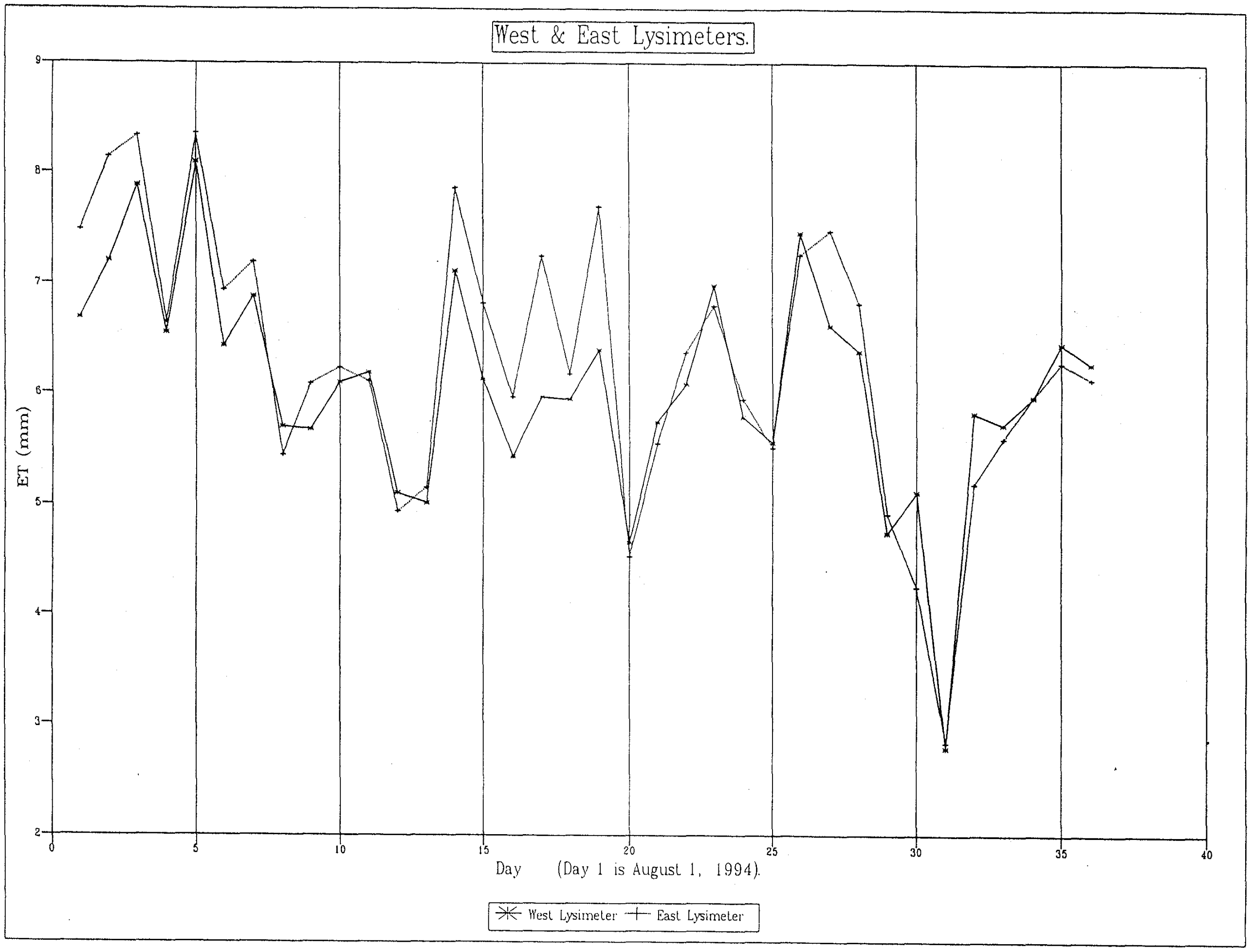

Figure 2. Predicted turfgrass water use in comparison to actual bermudagrass water use in the West Lysimeter.

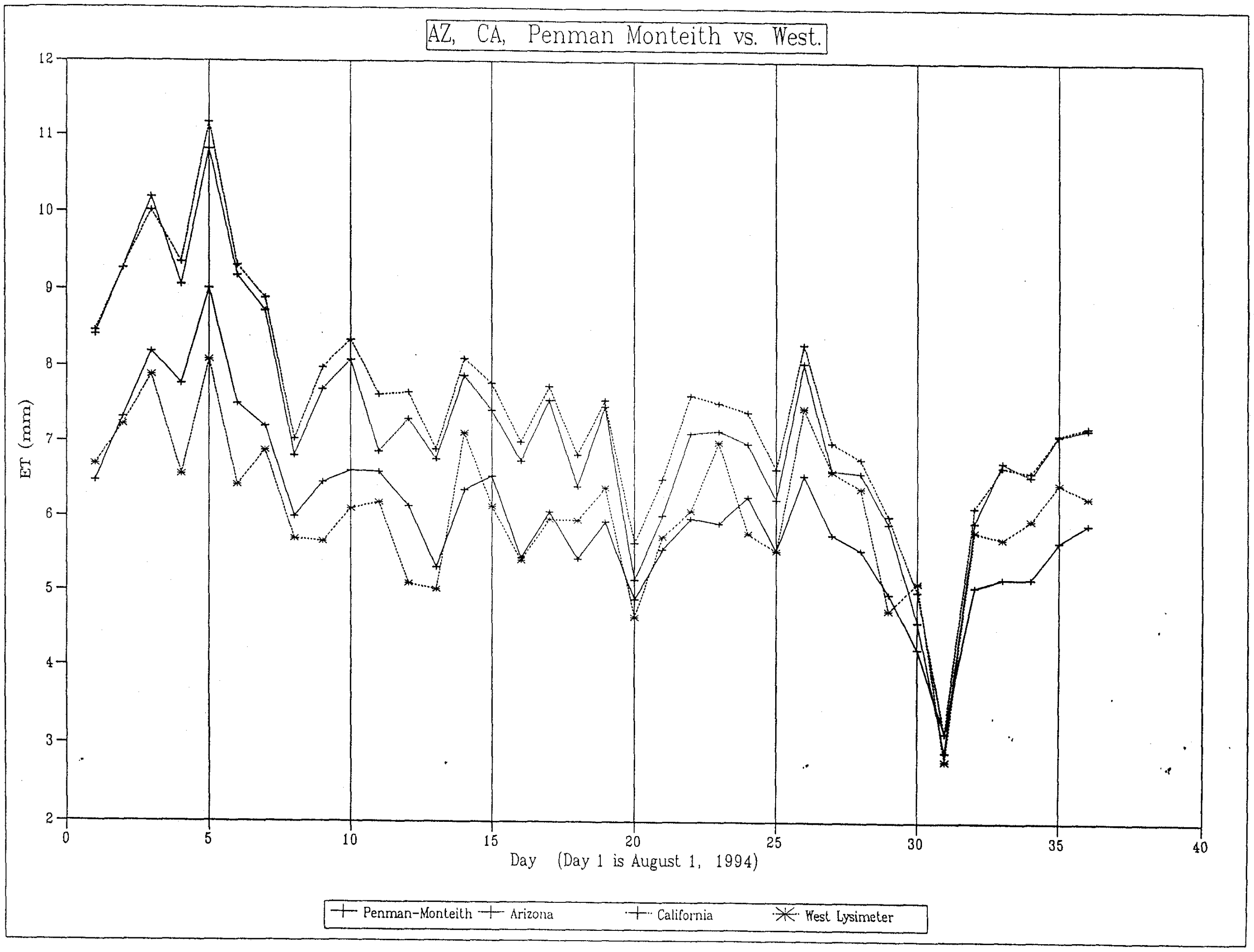

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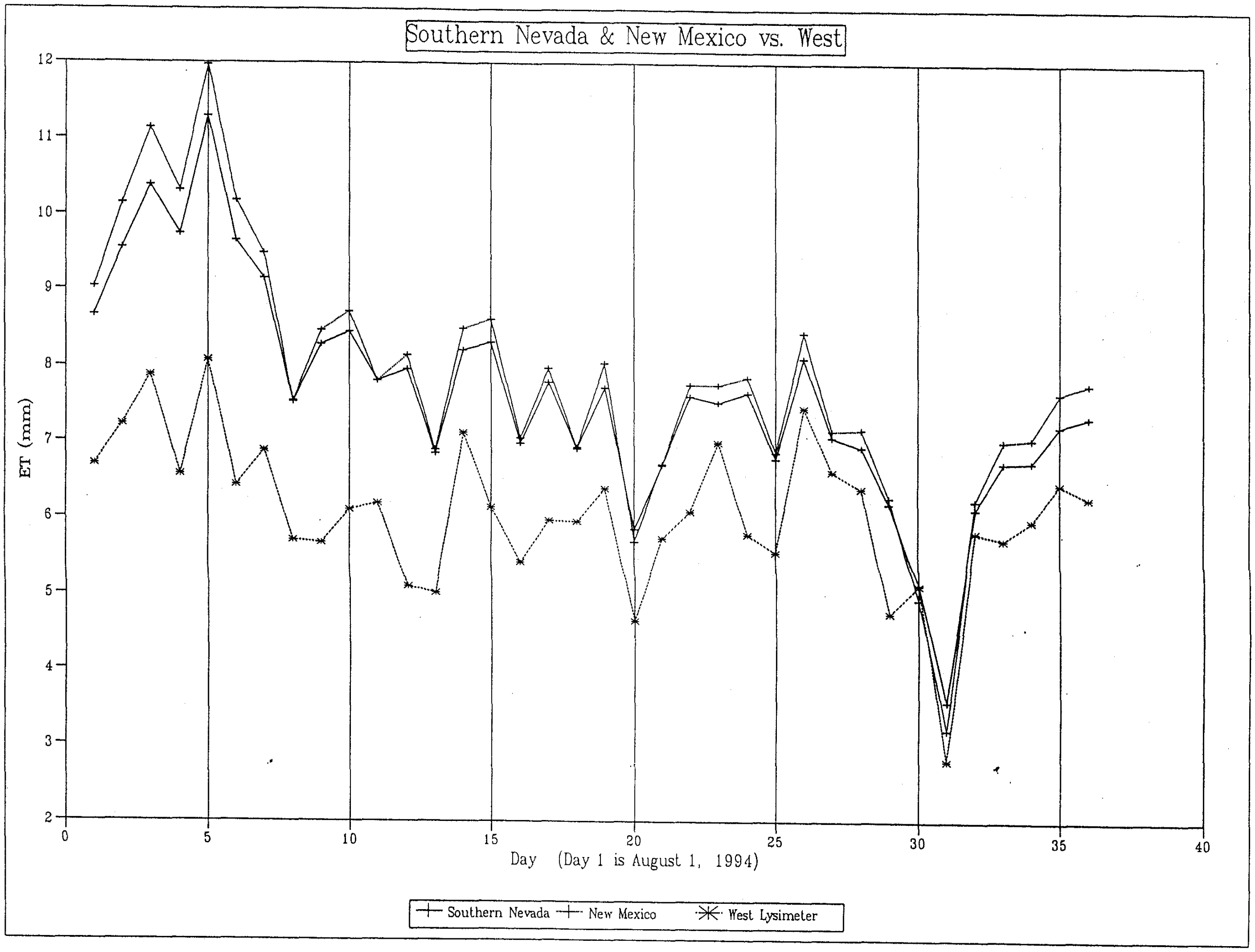
Figure 3. Predicted turfgrass water use in comparison to actual bermudagrass water use in the West Lysimeter.



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